SENSITIVITY TO THE EXTERNAL TEMPERATURE OF SOME GPS TIME RECEIVERS

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Abstract

It has been assumed until recently that GPS time receiver units (receiver+cables+antenna) have good stability and do not affect time transfer by more than 1 ns. Differences of a few nanoseconds sometimes observed during calibration campaigns have been attributed to external causes, such as multipath propagation, rather than to variations within the hardware.

The characteristic feature of most comparisons of GPS time receivers is their short duration. Normally the comparison takes place, at most, over one week. To observe the behaviour of GPS time receivers over a period of several months, an experiment has been organised involving three receivers of two types. All three were connected to the same atomic clock.

An unexpected sensitivity to external temperature was found in one type of receiver. This effect proved to be a function of the length and type of the antenna cable. In the most unfavourable case the sensitivity was 1.8 ns/°C.

INTRODUCTION

The GPS time receivers used for the purposes of time metrology have enjoyed until recently the excellent reputation of keeping one nanosecond whatever the environmental conditions. Several campaigns of differential calibration[1, 2, 3] have been conducted under this assumption. During these campaigns the receivers were compared typically over an interval of one or two days. These campaigns were rarely repeated in the same location. On the other hand, time laboratories are equipped in most of the cases with single GPS receiver. There have been only few opportunities to compare GPS time receivers for a period exceeding one week. Differences of a few nanoseconds sometimes observed during these comparisons have been attributed to external causes, as for instance multipath propagation,

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rather than to changes within the hardware. In only one case have two GPS receivers of different type been compared over a period of some months[4]. The differences between these receivers did not show fluctuations, however an inconsistency in the software of two receivers was noticed.

The experiment described in this paper was organized in order to observe the long–term behaviour of GPS time receivers. It covered the period November 22, 1989 — April 10, 1990. Three receivers of two types were involved. A sensitivity to the external temperature of one type of the receiver is demonstrated.

RECEIVERS

The experiment involved three C/A Code GPS time receivers, of two types used currently in numerous time–metrology laboratories. The receiver denoted R1 is of the first type, the receivers denoted R2 and R3 are of the second one. These two types of receiver are manufactured by two different makers and there are three major differences between them:

(a) Original design: the first type of receiver was designed for accurate time transfer; the second one was designed originally for differential geodesy and was later adapted for accurate time transfer.

(b) Internal delay: the first type has internal delay of about 50 ns, the second type one of about 400 ns.

(c) Frequency transmitted from the antenna to the receiver through the cable: the first type down-converts at the antenna level from the L1 frequency (1575.42 MHz) to 75 MHz and sends this signal by cable to the receiver. The second type transmits at 1575.42 MGHz directly to the receiver.

The second type of receiver (R1 and R2), as this experiment proves, shows sensitivity to the external temperature.

ANTENNA CABLES

Throughout the entire duration of this experiment, receiver R1 operates with a coaxial cable (type RG213U) of 33 m length provided by the maker.

Receivers R1 and R2 operate with different coaxial cables, all provided by the maker: 100 m (type H100 super low loss), 72 m (type H100 super low loss), 30 m (type RG213U low loss).

For simplicity of notation we will associate with the name of the receiver the length of the cable with which it was operated.

The table below gives the principal characteristics of these cables.

Length [m]	Type	Characteristic impedance [Ohms]	Attenuation at 1575 MGHz [dB/100m]	Operating temperature [°C]
100	H100 super low loss	50	15	−40 +80
72	H100 super low loss	50	15	−40 +80
33	RG58CU	50	40	−40 +80
30	RG213U low loss	50	30	−40 +80

ORGANIZATION OF THE EXPERIMENT

The three receivers use separate antennas located on the same roof. The differential coordinates of the antenna phase centres are known with uncertainties of a few centimetres.

The three receivers are programmed with the same schedule including 26 tracks per day.

The receivers are connected to the same master clock generating UTC(OP). The comparison consists in the computation, for each track i, of the time differences:

$$dt(i) = [\mathrm{UTC(OP)} - \mathrm{GPS}]\mathrm{Rec.A} - [\mathrm{UTC(OP)} - \mathrm{GPS}]\mathrm{Rec.B} \ ,$$

or, using abbreviations,

$$dt(i) = \mathrm{Rec.A} - \mathrm{Rec.B} \ ,$$

and then in computing the daily mean DT of dt(i).

RESULTS

The comparison of the three receivers is realized in several steps illustrated by Figures 1 through 4:

Figure 1 — First comparison (November 22, 1989 to January 12, 1990). Receiver R2 operates with the 100 m coaxial cable: receiver R3 operates with the 30 m coaxial cable. Differences between R2(100m) and the other two receivers reach a peak to peak value of 20 ns. Receivers R1(33m) and R3(30m) differ, peak to peak by 3.2 ns with a standard deviation of 0.6 ns over a 50–day period of comparison. The deviations of R2(100m) are strongly correlated with external temperature.

Figure 2 — Second comparison (January 13 to 22, 1990). The cables and antennas connected to R2 and R3 are interchanged. Receiver R3(100m) is now sensitive to the temperature.

Figure 3 — Third comparison (January 23 to March 20 1990). Receiver R2 now operates with the 72 m cable and R3 is connected to its original 30 m cable. A sensitivity to the temperature is observed for R2(72m), but is less strong than that for R2(100m). The differences peak to peak between R1(33m) and R3(30m) reach 2.4 ns; the standard deviation for the 56-day period of experiment is 0.6 ns.

Figure 4 — Fourth comparison (March 21 to April 10, 1990). Receiver R2 operates with the 30 m cable. The standard deviation between R2(30m) and R1(33m) is found to be 0.3 ns for a 20-day period of comparison. Peak to peak differences of 3.5 ns between R3(30m) and two other receivers are observed; these differences are correlated with temperature.

The observations described in the above comparisons show that standard deviations of daily means depend on the sensitivity to temperature of the receivers used: they decrease when sensitivity is reduced. Figure 5 shows the differences of individuals values $dt(i)$ between R2(100m) and R1 during one day: November 24, 1989. We observe a clear correlation with temperature. This effect induces an increase of the daily mean standard deviations.

CONCLUSIONS

1. The data obtained from receivers R2 and R3, both of the second type, are correlated with the external temperature.
2. This correlation depends upon the antenna cable. With the 100m cable (type H100 super low loss) recommended by the maker, the variation reaches 1.8 ns/xC.
3. Errors arising from changes in external temperature should be reduced to less than 1 nanosecond over the domain of usual temperatures for harmonization with other instrumental errors and potentialities of GPS: this achievement needs the sensitivity to be reduced to 20ps/xC.
4. Time-metrology laboratories should be equipped with at least two GPS time receivers (preferably three) to detect abnormal behaviours linked for instance with environmental conditions.

REFERENCES

1. J. A. Buisson, O. J. Oaks and M. J. Lister, *Remote Calibration and Time Synchronization (R-CATS) Between Major European Time Observatories and the US Naval Observatory using GPS*, in Proc. 17th PTTI meeting, pp. 201–222, 1985.
2. W. Lewandowski, M. A. Weiss and D. Davis, *A calibration of GPS Equipment at Time and Frequency Standards Laboratories in the USA and Europe*, in Proc. 18th PTTI meeting, pp. 265–279, 1986, [also in Metrologia, 24, pp. 181–186, 1987].
3. M. A. Weiss and D. Davis, *A Calibration of GPS Equipment in Japan*, in Proc. 20th PTTI meeting, pp. 101–106, 1988.
4. D. Kirchner, H. Bessler and S. Fassl, *Experience with two collocated C/A code GPS receivers of different type*, in Proc. 3rd European Time and Freq. Forum, pp. 94–103, March 1989.

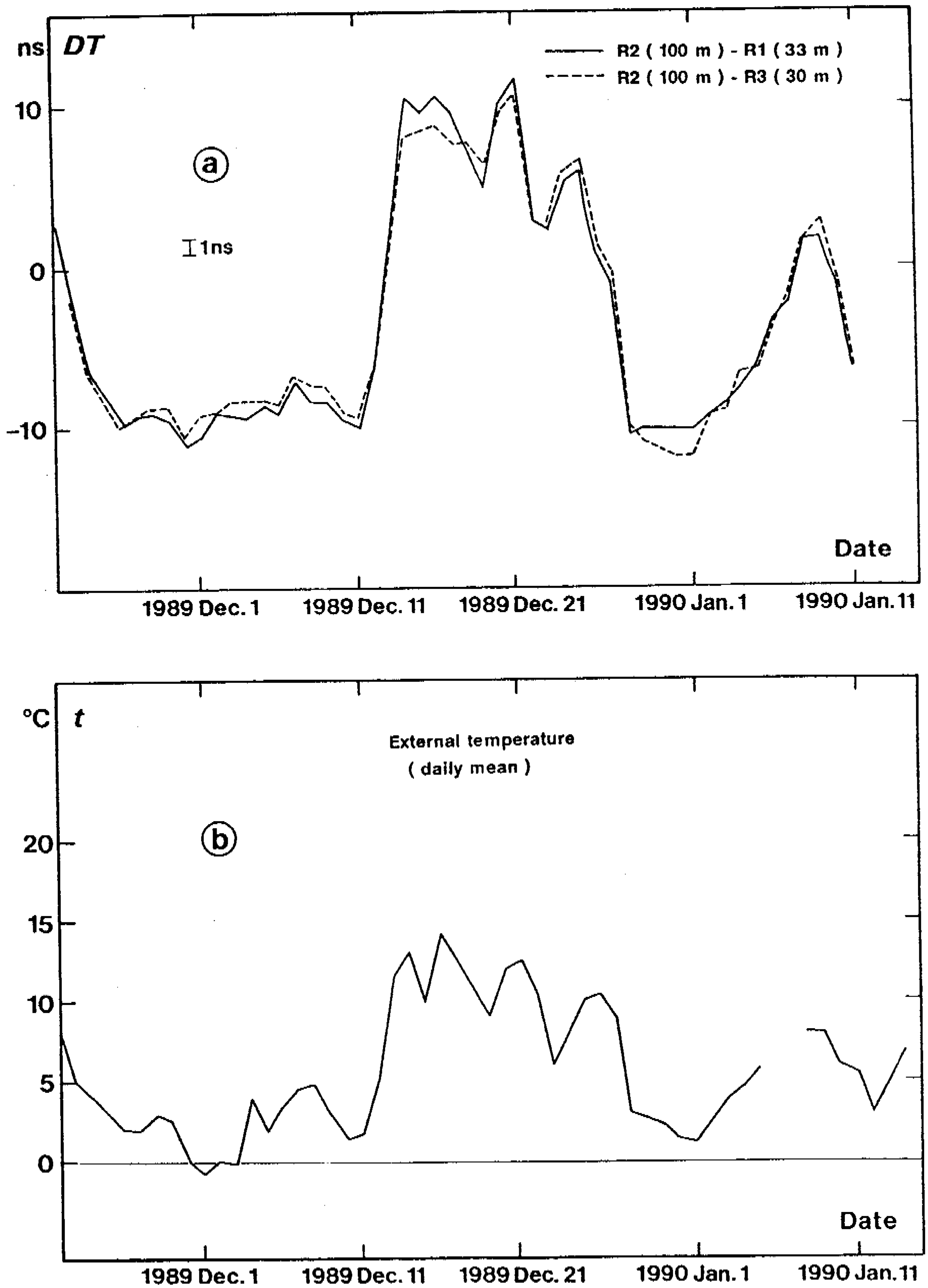


Figure 1. First comparison.

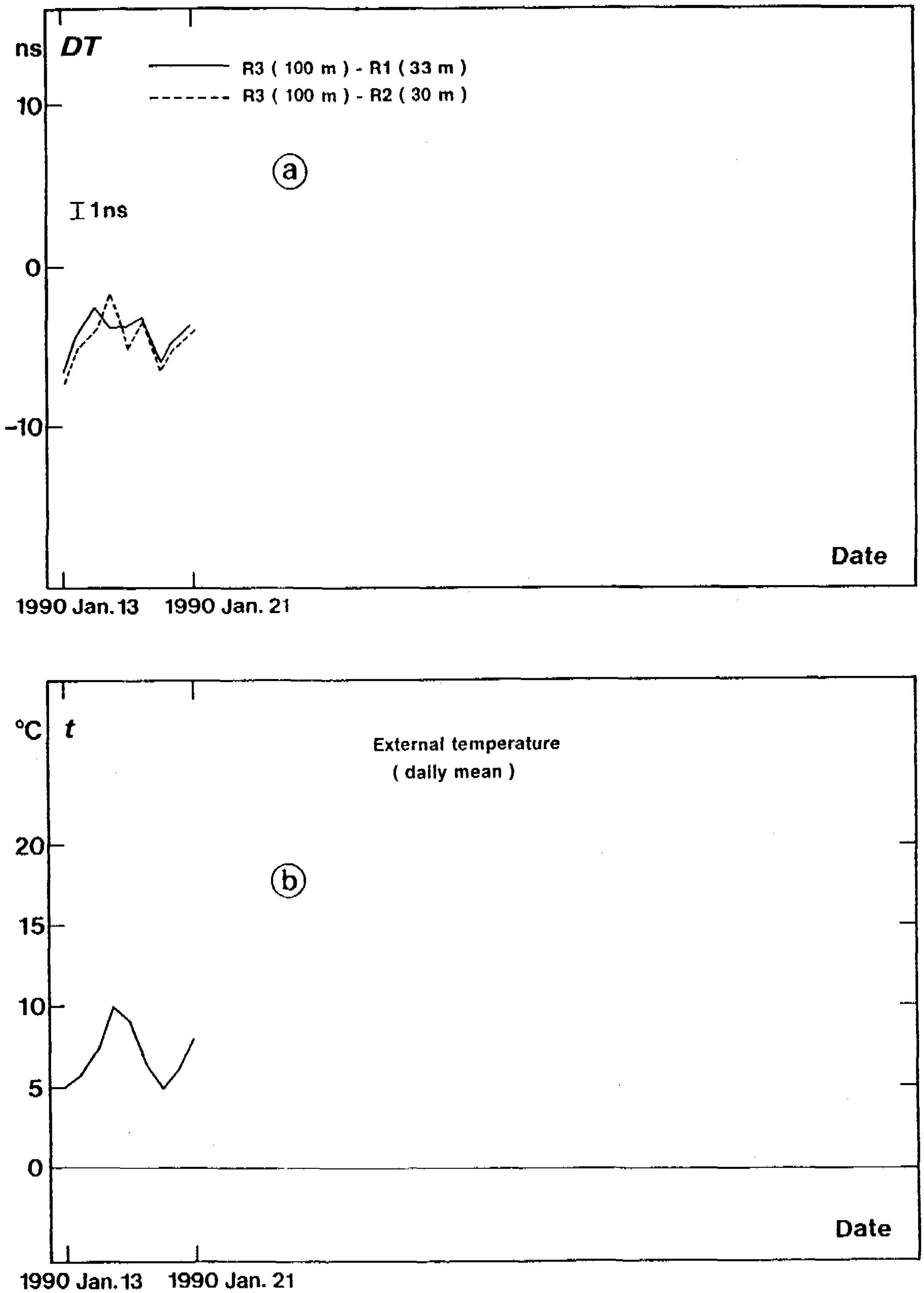
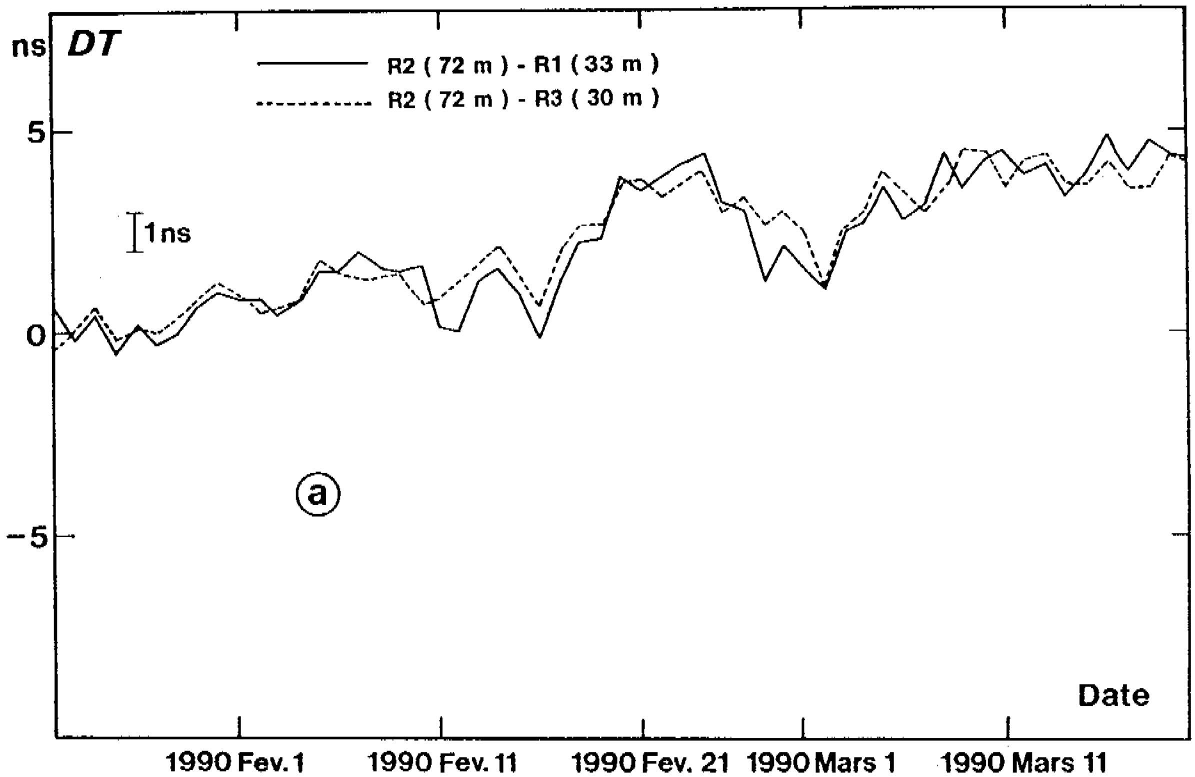
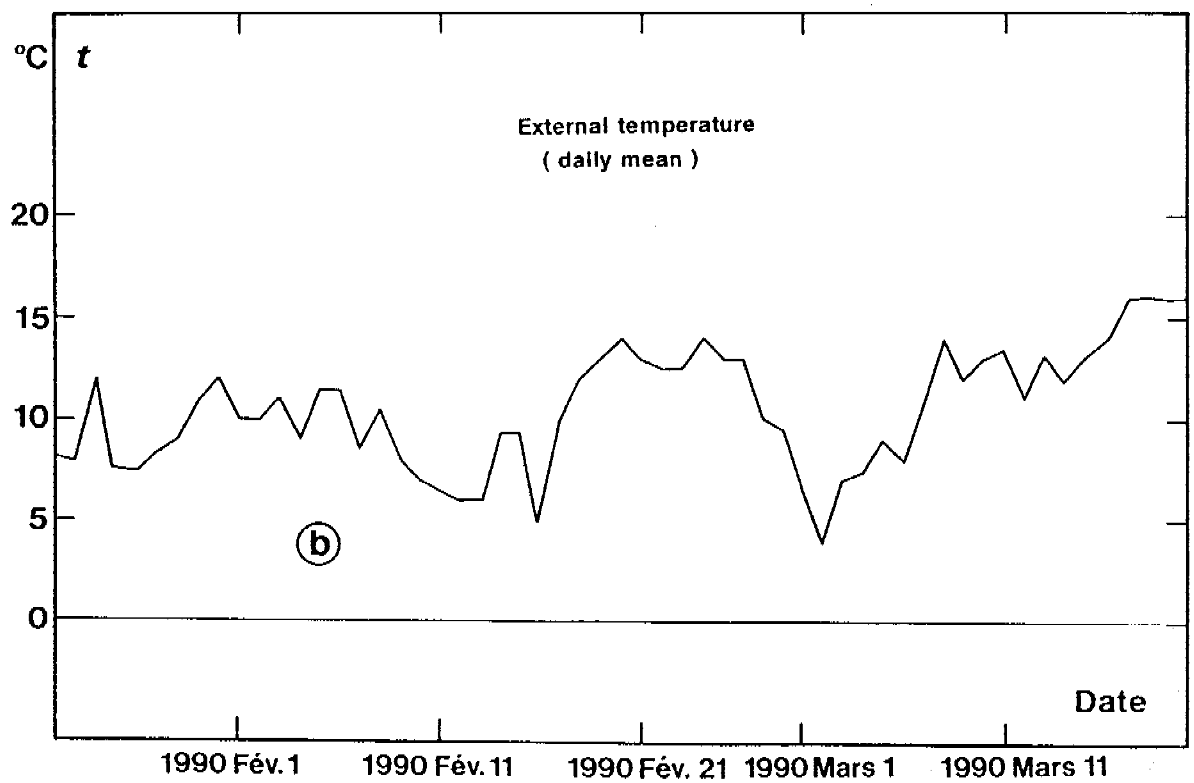


Figure 2. Second comparison.





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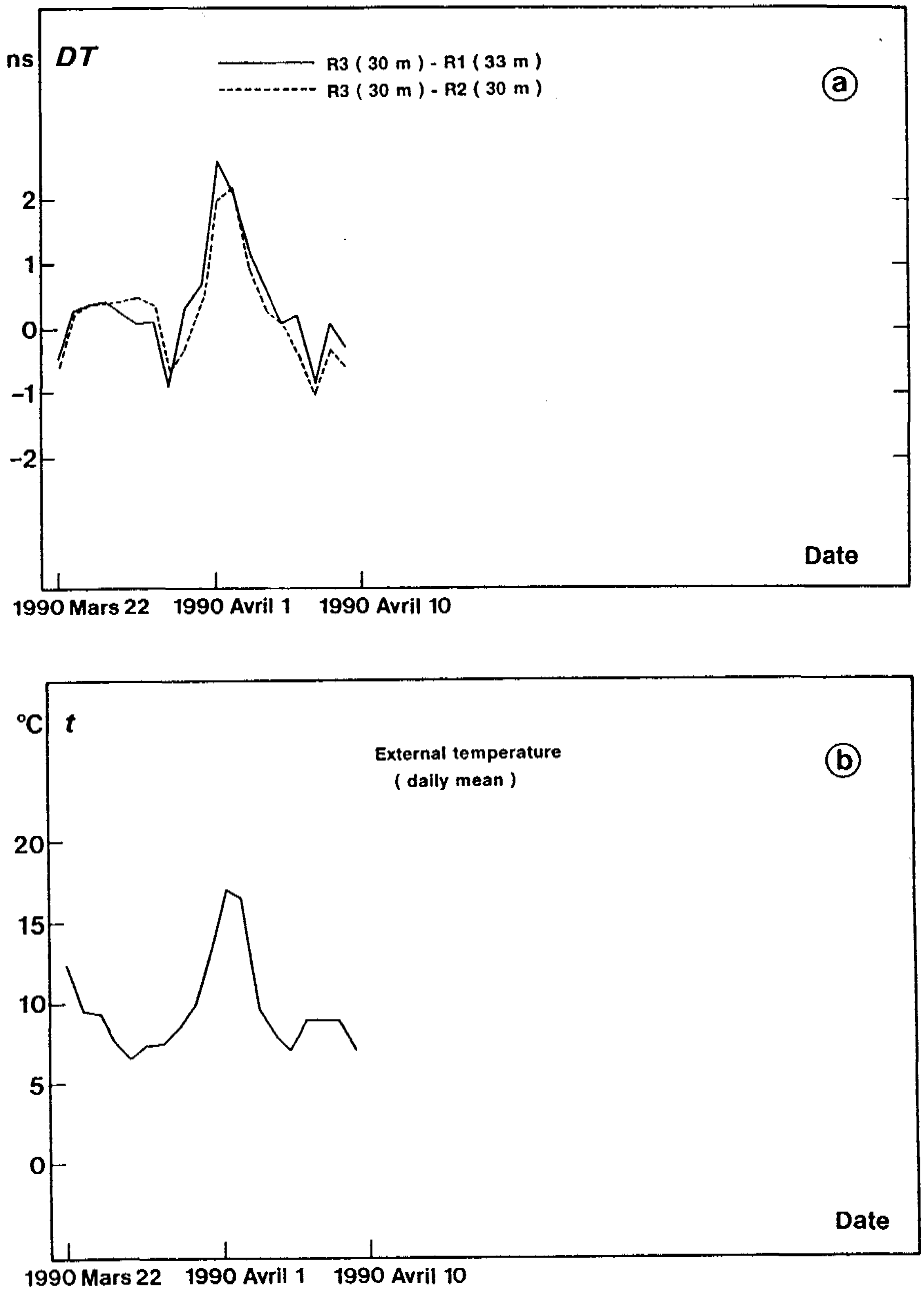

Figure 4. Fourth comparison.

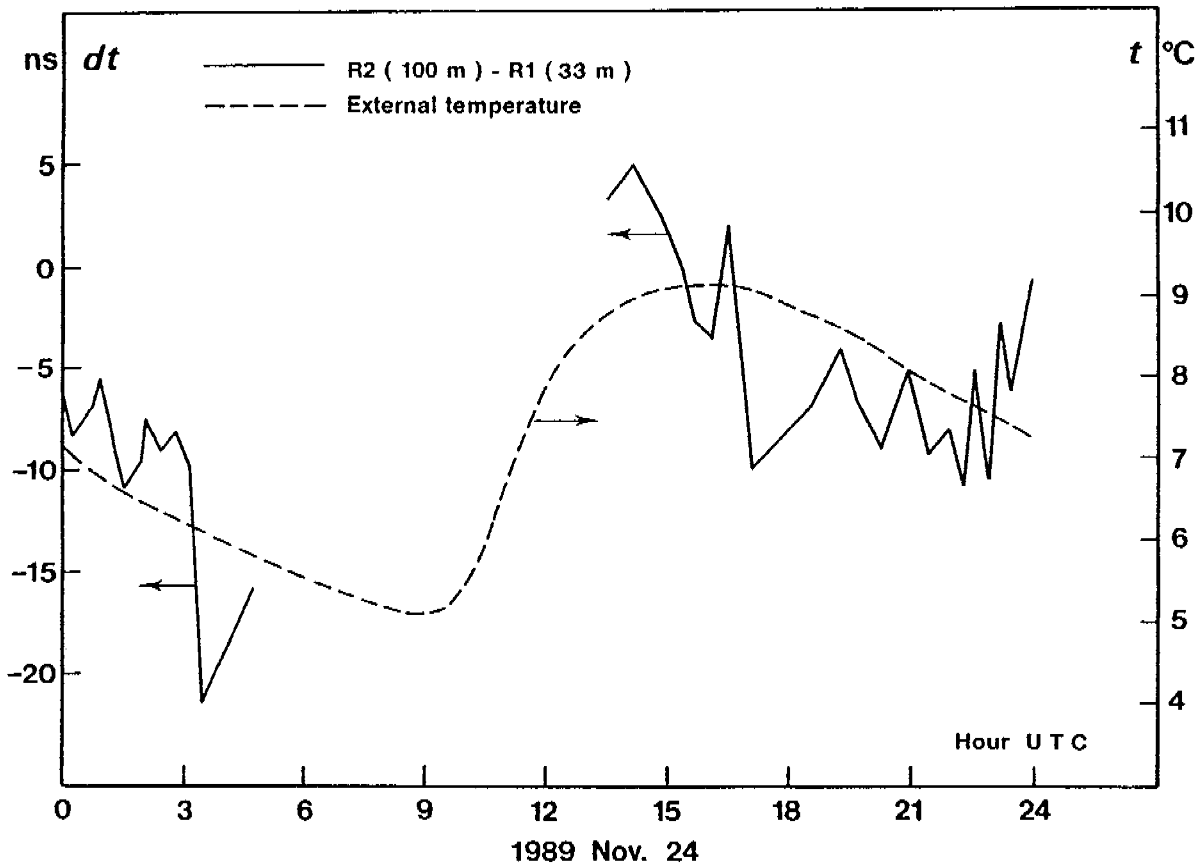

Figure 5. One day period of comparison between receivers R2(100m) and R1(33m).